FARMERS' BULLETIN 1098

UNITED STATES DEPARTMENT OF AGRICULTURE

DUSTING MACHINERY for Cotton Boll Weevil Control

THIS bulletin is intended to aid the prospective purchaser of dusting machinery for cotton boll weevil control in selecting a satisfactory model and one adapted to the needs of his particular farming conditions. Different localities frequently require different types of machinery, and the farmer should make sure he is securing one suitable for his needs. In case of questions not covered in this bulletin interested parties are invited to correspond with the Delta Laboratory, United States Bureau of Entomology, Tallulah, La.

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief
Washington, D. C. January, 1920

DUSTING MACHINERY FOR COTTON BOLL WEEVIL CONTROL.

ELMER JOHNSON, *Agricultural Engineer, Bureau of Public Roads*, and
B. R. COAD, *Entomological Assistant, Bureau of Entomology.*

CONTENTS.

	Page.
Factors affecting machine construction	5
Characteristics of available labor	5
Area to be treated	6
Nature of field	7
Night operation necessary	7
Characteristics of poison used	9
Type of dust cloud required	10
Manner of packing the poison	11
Machine construction	12
Hand guns	12
Operating area	12
Limitations and principal uses of hand guns	13
Capacity of the hopper	14
Weight and balance of gun	15
Elevation of dust delivery	15
Machine construction—Continued.	
Hand guns—Continued.	
Inefficiency of two-row hand guns	15
Nozzles	16
Dust-feeding devices	16
General construction	16
Power machines	18
Truck	20
Engine	21
Duster	22
Lighting	23
Distributing system	25
Exhaust	27
Advantages and disadvantages of power dusters	27
Wheel-traction duster	28
Summary and conclusions	30

FOR the past several years the Bureau of Entomology of the United States Department of Agriculture has conducted extensive experiments on the control of the cotton boll weevil by poisoning, and the results have justified the adoption of weevil poisoning on a commercial scale. The experiments have been under the direction of the Delta Laboratory, at Tallulah, La., and have been largely in that neighborhood. In 1918 practical control of some 35,000 acres of cotton was undertaken under the supervision of agents of the Delta Laboratory, and so satisfactory was the outcome that general information on the subject was released and in 1919 poisoning as recommended was attempted by the farmers themselves. On the whole, the results were satisfactory, and it appears that the practice of poisoning cotton for boll-weevil control will spread rapidly.

A determining factor in the results of poisoning is the use of suitable dusting machinery, and so important is this that much attention has been devoted to the development of satisfactory machines of different types. Just now there is great need for placing the accumulated information on the subject in a form available for use. Many manufacturers are planning to build dusting machinery and are absolutely at sea as to the requirements of a satisfactory machine. Furthermore, farmers desire definite information to guide them in purchasing machines that will answer their purpose. The present bulletin, therefore, is intended to serve as a report of progress and to supply as far as possible the two needs just mentioned.

Before taking up the question of machine construction it probably will be well to review briefly the poisoning work from the standpoint of the machinery used. Naturally the poisoning tests as first conducted consisted of small plat experiments where at most only a few acres in one locality were treated. For this purpose, of course, a small-capacity hand-operated dust gun was eminently suitable. Consequently a few changes were made in certain existing guns, which rendered them fairly satisfactory for strictly experimental work and they were utilized throughout the early stages of poisoning. The results of these early plat tests were so favorable, however, that practically the first year's poisoning as arranged in cooperation with certain planters called for the treatment of very large areas. In fact, as mentioned, some 35,000 acres of cotton were treated during that year (1918), and this, of course, necessitated an immediate supply of machinery of the largest capacity possible.

Existing types of power machines were examined and tested, and it was found that nothing suitable for the work was available. Nevertheless, owing to shortage of time, it was necessary to adapt some of these machines to the requirements of cotton dusting and as far as possible to utilize the machinery then existing. Consequently, certain types of orchard dusters were selected, and the necessary changes made to permit their operation in cotton fields. In the effort to utilize these machines, however, many difficulties were encountered which could not have been anticipated, and it became obvious that the operation of poisoning cotton was going to be much more difficult and involved than had been expected. Many factors contributed to cause delays in the operation of the machines, and as practically the entire system of weevil control is based on dusting at exactly the right time, these delays were very detrimental. In fact, it was soon seen that the success or failure of poisoning depended largely on being able to get the cotton treated in the right manner at exactly the right time, and any delay or interruption in this schedule either made the operation much more difficult and expensive or prevented satisfactory results.

In view of the obvious importance of this consideration, the writers undertook an intensive study of the factors affecting the operation of cotton dusting machinery and the actual difficulties experienced. This involved the use of a considerable number of various types of machines throughout the season over large areas. As a result of two years' work of this nature, a rather comprehensive idea has been secured of the conditions which are going to influence the operation of cotton dusting machinery and the difficulties which are most likely to be encountered.

In connection with the entire discussion of cotton dusting, it must be remembered that this operation is now being placed on an extensive basis rather than an intensive one. Generally speaking, in

the past the use of all insecticides has been comparatively limited in scope and has practically always been in conjunction with some crop raised under more or less intensive cultural conditions, such as truck crops, orchard crops, tobacco, etc. In all of these crops the areas are comparatively small and the labor utilized has been, generally speaking, of a fairly intelligent type. With the inauguration of cotton dusting, however, the operation is removed entirely from this class and placed on a tremendously extensive basis involving the use of very large areas and a comparative shortage of labor. Consequently, machinery adapted for dusting work such as has been conducted in the past would not serve for cotton dusting and it was absolutely essential to take up the construction of specialized types.

It is of course impossible to make positive predictions as to the future for cotton dusting machinery. Results of large-scale experiments extending over a number of years have been so favorable, however, that the conclusion appears justified that weevil poisoning will prove profitable and thus be adopted in practically all portions of the Cotton Belt. It is, of course, going to involve many failures and partial failures at the outset, but the weevil damage is so great and a method of control so greatly needed that poisoning is bound to prevail on its obvious merits. Just how rapidly it will be taken up is another question, but the importance of developing machinery suitable for this work is well shown by the fact that the weevil has now infested almost the entire cotton area of the United States and there are probably at least 25,000,000 acres of cotton subject to more or less severe weevil damage every year.

For the purpose of this bulletin the different conditions existing which affect cotton-dusting operations, especially as regards the machinery construction, are first presented, then the machinery question itself is taken up and the progress which has been made toward meeting the different problems involved therein are outlined.

FACTORS AFFECTING MACHINE CONSTRUCTION.

CHARACTERISTICS OF AVAILABLE LABOR.

Since in most cases dusting machinery will be operated by plantation negroes, it must be adapted to their capacities. As a rule, these laborers are very limited in their ability to utilize a new implement. They have no mechanical training and as a consequence they are unable to operate a complicated machine requiring elaborate adjustments or repairs. Furthermore, many of them are very careless. About all that can be done, therefore, is to train them in a few rudimentary operations and then attempt to see that they carry them out efficiently. Every step toward simplifying the operation and maintenance of the dusting machine is a tremendous advance toward making it satisfactory and efficient.

Furthermore, the average plantation hand avoids laborious operations, and this fact has special significance when the future use of hand dusters is considered. The most prejudiced advocate of these machines could certainly not call them easy to operate. In fact, nearly all operations with hand dust guns in the past have usually been so arranged that they involved working these machines for only a few hours a day. This will not suffice for cotton, and great difficulty has always been experienced in securing labor to operate these machines continuously.

Another serious drawback to the use of hand dust guns is the reluctance of most plantation negroes to become wet with dew. They have a dread of this amounting almost to a superstition and it is very difficult to persuade them to tramp back and forth through the dew-drenched cotton field. On the other hand, as will be explained on subsequent pages, it is desirable to do as much dusting as possible while the plants are moist with dew.

Generally speaking, the negroes fear the poison. This is probably more or less due to the fact that a great many have had or have heard of injuries experienced while treating cotton with paris green a number of years ago, when this operation was very common for leafworm control. Paris green is decidedly injurious to man when any considerable amount comes in contact with the skin, and while this is not true of calcium arsenate, which is now being recommended for boll-weevil control, it is very difficult to make the laborers distinguish the difference. Consequently, they are very reluctant to utilize any type of machinery which exposes them to a considerable amount of dust, as in the case of hand guns where they are walking through the dust cloud most of the time. Then too, they are likely to attribute any type of illness, real or imaginary, to the poison when there has been any exposure to it. In reality, there is little danger to man from the ordinary use of calcium arsenate as long as reasonable precautions are taken, but extreme exposure to the dust cloud may cause injury in time and is at the least very annoying.

It is desirable, therefore, so to construct the machinery that the operator will be exposed to a minimum amount of dust.

AREA TO BE TREATED.

The area to be treated is an important consideration. As far as the plantation is concerned, this will vary from the small farm with perhaps 5 acres of cotton to the large plantation of thousands of acres. For example, one property, where a great deal of the experimental work of the Department of Agriculture has been conducted so far, plants about 16,000 acres of cotton each year. It is thus necessary to provide machinery suitable for organizations ranging from a very few acres to thousands of acres.

The size of the individual field also varies tremendously, especially in different districts but, generally speaking, throughout most of

the territory where weevil damage is severe the cotton crop is divided into fields, or "cuts," ranging from 1 to 15 or 20 acres in extent. These usually are bounded and separated from other cuts by ditches, turn rows, headlands, fences, timber, etc. In certain districts, especially where the rainfall is fairly light, these cuts are frequently very large and the rows comparatively long. On the other hand, in districts of heavier rainfall (and these are the districts where weevil damage is most severe) the necessity for drainage decidedly limits the size of the cut and as a consequence in a great majority of cotton fields rows 1,000 feet long are rare. In addition, a considerable portion of the cotton belt is still only partially cleared and this naturally results in all kinds of irregular and odd-shaped fields. In planning to purchase cotton-dusting machinery the farmer must consider carefully the nature of his fields and the actual ease of operation of different types of machines. Naturally in large open fields with good facilities for turning at row ends and with lengthy rows, large power machinery is desirable, but as the fields become smaller, the rows shorter, and turning more difficult, smaller machines with a more limited capacity are necessary.

NATURE OF FIELD.

Another important consideration is the presence of stumps or other obstructions in the fields. Generally speaking, "new ground," where stumps are prevalent, is a fertile soil and thus adapted to producing the highest yield of cotton; on the other hand, this nearly always adjoins timber or other weevil hibernation quarters and thus receives the heaviest infestation in the spring and requires the greatest amount of treatment for weevil control. It is not customary in the cotton belt to remove stumps from land on clearing but the practice is to allow them to rot out, and it thus becomes necessary to dust a large number of fields of cotton of high potential productivity with a heavy weevil infestation and so full of stumps that it is almost impossible to drive a team through them. Figure 1 shows a field of this type which was poisoned at Scott, Miss., during 1918 and 1919. Driving through such a field during the day would be difficult enough, but at night when the stumps are more or less hidden by the plants and many are absolutely invisible, even with the best of lights, it becomes a serious problem. It is impossible to keep from running upon a stump occasionally and where wide distributing systems are utilized extending several rows beyond the side of the machine, it is impossible to avoid occasional collisions.

NIGHT OPERATION NECESSARY.

The importance of night operation has already been mentioned several times, but it is probably well to outline briefly the necessity for this. The basic principle of the present system of cotton dusting

requires that every portion of the cotton plant be thoroughly covered by the fine particles of poison. This means that a dust cloud must be created which will drift throughout the cotton. Of course it is desirable to have as much of this adhere to the cotton plant as possible, and thus the presence of dew greatly increases the efficacy of the application. In addition to this, however, atmospheric conditions must be just right or the poison has a tendency to drift off and not settle down through the plants. This is, of course, largely a question of humidity, air movement, etc., and by far the best conditions for dusting are experienced at night when the air is calm and the humidity high and when the dust cloud will drift through and permeate to every portion of the cotton plant. Occasionally days

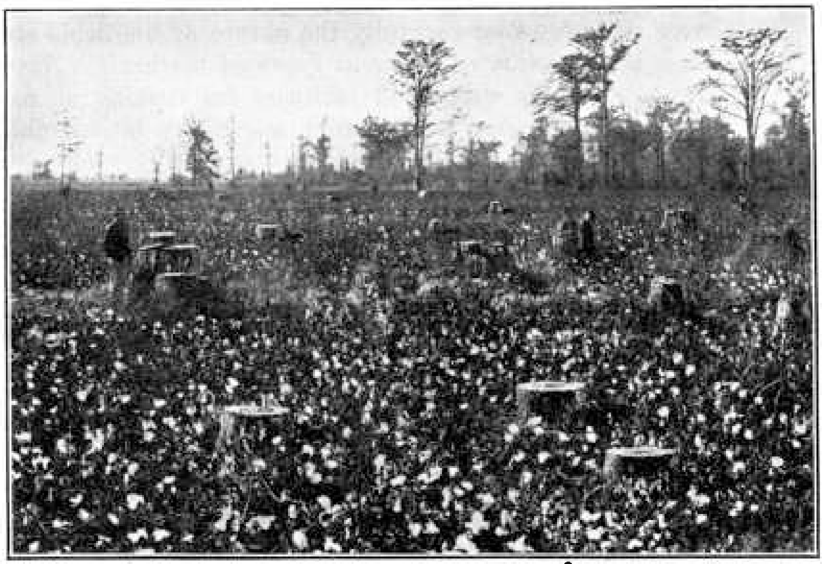

FIG. 1.—Mississippi cotton field showing stumps among which dusting machine must operate.

suitable for dusting are experienced, such as calm, cloudy, misty days, but these are rare and usually there is sufficient wind throughout the day to cause the poison to drift away above the tops of the cotton plants and thus fail to cover them thoroughly. For this reason, with the machinery now available, all efforts have been aimed toward doing as much dusting as possible during the night and operating during the day only when necessary. On the other hand, as will be shown later in this bulletin, the machines now available are limited in their blowing capacity, and it seems quite possible that with an increased air blast, such as will undoubtedly be introduced on some machines in the future, it may be possible to get the dust distributed throughout the plants even under ordinary daytime conditions and thus render night operation unnecessary. Until such machinery is built, however, plans should be made for night operations.

In addition to the troubles already pointed out as incidental to night dusting, there are many other difficulties. At night the labor is even more careless and inattentive than during the day and is supervised with much more difficulty. A small breakdown which could be easily repaired in daytime and would occasion very little trouble becomes very difficult at night and will often cause serious delay. Machine repair work by the light of a lantern is not a thing of joy, and is fraught with difficulties which must be experienced to be appreciated. Furthermore, driving is much more difficult at night. During the day it is easy to see and gauge the depth of the ditches, but these are often hidden by weeds at night and consequently the machines are subjected to very severe jolts and strains. In fact, one of the greatest difficulties which has been experienced so far in the construction of dusting machines has been building them strong enough to withstand their rough treatment, and this is undoubtedly due as much to night operation as to any other factor.

Another feature of night operation is the presence of dew on the plants and the fact that all portions of the machine coming in contact with these plants become so heavily laden with dew that special devices must be arranged to prevent this from interfering with machine operation. These will be discussed in detail later in the present bulletin.

CHARACTERISTICS OF THE POISON USED.

For the purpose of cotton dusting, the Department of Agriculture is now recommending calcium arsenate, and as this compound varies widely in its physical properties, the different types have been tested and the one form most suitable for the work has been selected and particularly recommended. This material is much lighter than the ordinary insecticides; in fact, the standard specifications call for a volume of 80 to 100 cubic inches to the pound. The characteristics of this material must be considered very carefully in planning dusting machinery. Probably the most important point in this connection is its stickiness and tendency to pack on the slightest occasion. This is especially pronounced during night operations when the humidity is high, and it has caused the elimination of many otherwise satisfactory features on dusters. It simply means that at no stage of the handling of the calcium arsenate from the time it starts through the hopper until it is blown out of the nozzles must there be any opportunity for it to pack or clog the machinery. Agitators must be provided in the hopper, therefore, for passing the material down to whatever feeding device is used. Furthermore, the feeder must be of such a nature that the material will not clog in it. Then, too, all delivery ducts, pipes, nozzles, etc., must be so arranged that there will be an absolutely free flow of the dust-laden air and no eddies or obstructions which will cause clog-

ging. In the case of hand guns, this frequently necessitates the use of some kind of agitator or vibrating arrangement to keep the dust in circulation; and in certain types difficulty has been experienced with feeding, due to the fact that where brush feeds are utilized, these will often dig out a sort of cavern for themselves in the mass of dust and then stop feeding.

As has been mentioned, a successful dusting consists in thoroughly covering all parts of the plants with the exceedingly fine particles of calcium arsenate. This, of course, means that the better the powder is broken up into its finest particles the more efficient the dusting and the smaller the amount required per acre. With the dusting machinery available when first tests of power dusters were conducted several years ago, it proved impossible to treat cotton satisfactorily with less than from 15 to 20 pounds of poison per acre. By improving the machinery, however, so that the dust is broken up better and thus distributed over a larger area, it has been possible to reduce this dosage to about 5 pounds per acre and secure the same satisfactory results, and still further improvement along this line appears possible. In fact, if it is possible to break up the powder into the finest particles and to distribute these evenly through the plants, there is sufficient volume in 2 pounds of poison to treat an acre of cotton satisfactorily. All efforts, therefore, should be bent toward improving this feature and thus reducing the poundage required. It is true that weevil poisoning is profitable at the present dosage, but when the extensive areas to be covered are considered the saving involved in a reduction of even 1 pound per acre in the dosage required will be enormous each year and well worthy of a most earnest effort.

TYPE OF DUST CLOUD REQUIRED.

The type of dust cloud necessary for successful cotton dusting also bears directly on machine construction, particularly in relation to the arrangement of the nozzles or distributors. At the outset it was considered advisable to use some adjustable type of nozzles so that they could be placed directly over the rows regardless of the row width. This was soon found to be impracticable, however, owing to the extreme variation of row widths within a field or even from end to end in the same row. Furthermore, it was found that it was not necessary to blow the material directly on the cotton, but that the powder which simply drifted on the plants would be just as efficient for the purpose of weevil control. Consequently all distributing systems are now arranged with fixed nozzles at approximately average row widths or a little wider, but with some system of deflectors which produces a solid cloud of dust extending through all the rows and filling the plants so completely that it does not matter whether the nozzles are over the rows or between them. Nearly always it has proved possible to poison a few extra rows beyond the actual exten-

sion of the distributing system by creating a sufficient dust cloud to allow it to drift. On favorable nights when the plants are thoroughly moist and when there is no breeze to blow the dust away, as many as 15 to 25 rows have been poisoned in this manner from a distributing system extending over only 5 rows. Figure 2 illustrates very well the type of dust cloud desired for a successful poisoning and shows how the dust penetrates between all parts of the cotton plant and thus renders unnecessary any efforts to place the nozzle directly over the row.

MANNER OF PACKING THE POISON.

Even the manner of packing the poison has a direct bearing on the machine questions involved. Unfortunately, a large portion of

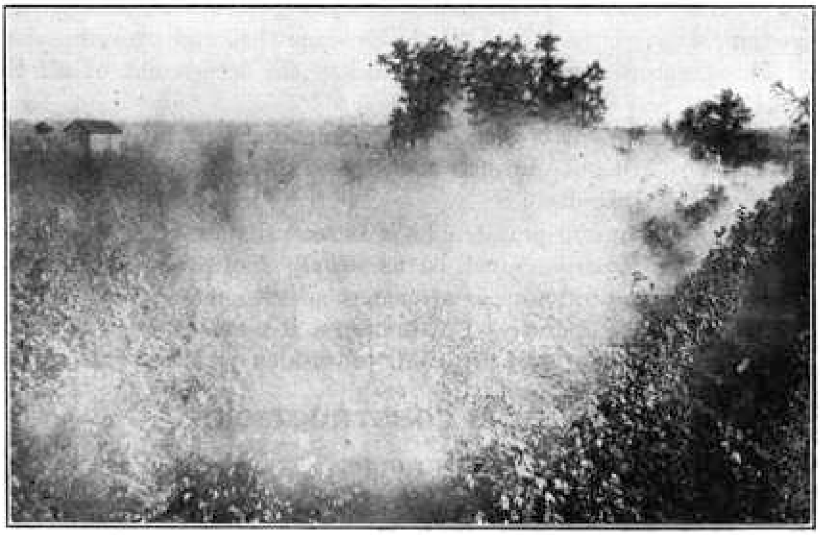

FIG. 2.—Type of dust cloud desired for successful treatment of cotton plants.

the poison purchased during 1918 was packed in light-weight barrels with paper liners. These paper bags were supposedly so arranged that when the head of the barrel was knocked in, the top of the bag would be untied and spread back over the barrel so that the poison would be dipped out without disturbing the paper. In reality, however, this practice was never followed, and it proved impossible to get the laborers to do it. The usual system was to knock in the head of the barrel hurriedly and then tear the top of the bag open. As the poison was lowered in the barrel the paper interfered with dipping and sections were constantly being torn from it. This resulted in the introduction of small bits of paper into the machine hopper with the dust, where it wound around the agitator and at last practically shut off the feed. The operators devote little or no attention to the actual amount of dust being discharged, simply noting that the regulator is set at the point at which they have been trained to open it and watch-

ing the hopper to see that it is always at least partially filled. Consequently, they would run along happily with the regulator open, the hopper full, and practically no dust coming out of the nozzles. This, of course, resulted in many spots of unpoisoned or partly poisoned cotton before the difficulty was discovered and corrected, and these spots served as points of weevil infestation for the remainder of the field. Even after the trouble was noted it was necessary to stop the machine for from 10 minutes to a half hour and clean out all the obstructions, causing a considerable loss of time.

In addition to this paper, small scraps of wood from the barrel heads were constantly getting into the machines, and in 1919 it was deemed desirable to try to sift the poison in feeding it into the hopper. For this purpose, the funnels utilized in hopper filling were built with a rather large mesh wire screening across the mouth; this expedient delayed the filling operation somewhat and proved useless, for the operators very carefully knocked the screen out of all the funnels.

For these reasons it is strongly recommended that all poison used be purchased in tight, unlined containers, thus obviating at least a portion of the difficulty.

From the foregoing paragraphs it is seen that to be a success the cotton-dusting machine must be as nearly fool-proof as possible. It must require a minimum of attention, adjustment, and repair, and must be simple to operate. Furthermore, it must be built to stand very rough treatment and all kinds of sudden jars and shocks.

MACHINE CONSTRUCTION.

HAND GUNS.

Many types of hand guns have been tested but so far the only ones found satisfactory for cotton dusting have been more or less similar in general plan of construction. Figure 3 shows two of these guns in operation and gives a general idea of their form. The guns are all of light-weight, sheet-metal material, and usually consist of a fan housing and dust hopper, either united or separate, with some simple crank and gear arrangement for securing a reasonable fan speed. Several feeding devices are utilized, some of which introduce the dust into the air duct beyond the fan while others introduce the dust directly into the fan, which discharges it into the air duct. This air duct then leads through a short tube to some type of spreader nozzle for delivery on the plants. All of these machines are provided with some simple strap device for suspending them from the shoulder of the operator.

OPERATING AREA.

In figuring on the use of the hand gun, it is, of course, necessary to take the speed of operation into consideration. A considerable

number of observations based on small areas have shown an average speed of operation of about 1 acre per hour per gun. It has been found, however, that this speed can not be maintained in continuous operation. In fact, the operation of dusting with a hand gun has proved so laborious that in most of the work conducted so far, dusting has been confined to a few hours in the early morning and late evening. In this way it is possible for a man to operate a gun for from three to four hours in the morning from daybreak onward and for about the same period just before dark in the evening. Even by arranging a schedule in this manner, however, it has been found that the maximum area that a laborer can be expected to dust in a day is about 5 acres, and in reality as much as this is seldom covered. So far little attempt has been made to utilize hand guns at night, but this is quite as feasible as operating them during the day, especially

FIG. 3.—Hand guns in operation in a cotton field.

if the operators are equipped with some simple type of headlight, such as the ordinary carbide or kerosene lights made for attachment to the hat. In the tall cotton where it is difficult to direct the dust on the top of the plants when walking on the ground, and in fact even in the smaller cotton, it has frequently proved much more satisfactory to operate hand guns from the back of a mule. The animal quickly becomes accustomed to the noise of the gun and much more speed can be made with much less labor by riding a mule down the row and cranking the gun from the saddle.

LIMITATIONS AND PRINCIPAL USES OF HAND GUNS.

Considering the matter as a whole, the hand guns utilized so far can hardly be classed as more than a temporary expedient pending the development of something more satisfactory. In order to conserve weight a great deal of attention is always devoted to lightness of construction, and as a result it has been very difficult to secure a hand gun which would stand up under the service required of it

in cotton dusting. The rough usage has usually proved too much for the machines, and as a rule it has been necessary to figure on a supply nearly double the actual requirement in order to have enough to replace breakage. Furthermore, from the standpoint of the labor supply the hand guns apparently are seldom practicable on areas exceeding a very few acres. In every case known to the writers in which poisoning with hand guns has been attempted on areas amounting to 100 acres or more, the labor difficulties were such that very unsatisfactory results were secured, and it seems generally inadvisable to attempt to utilize hand guns on such areas.

Probably one of the most important uses of the hand gun consists in its operation in conjunction with larger power machinery. In nearly all places there are a certain number of cuts or portions of cuts where, on account of stumps or some other features of this nature, power machines can not well be operated. In such cases the efficiency of the power machinery is greatly increased by the possession of a few hand guns for occasional use in caring for these unhandy places, thus permitting more rapid operation of the power machines. Quite frequently the large-scale work has been so arranged that approximately 10 hand guns were used with profit in conjunction with each power machine. Furthermore, they are of additional value early in the season when the weevils are frequently confined to comparatively small spots of the larger cotton in the fields, and it is possible to go in with hand guns and dust only a few acres and thus at least delay the general infestation of the fields.

CAPACITY OF THE HOPPER.

One of the most important features of hand-gun construction is the capacity of the hopper. Owing to the lost time involved in filling when it is necessary to walk some distance to the supply barrel, it is desirable to arrange the machine to carry as much poison as practicable. On the other hand, this quantity is limited by the weight of the machine. Most of the machines manufactured so far weigh from 10 to 12 pounds empty and will contain from 5 to 7 pounds of dust. This means that the hopper must have a capacity of from 500 to 700 cubic inches. In this connection it should be noted, of course, that the hopper capacity should in reality mean the amount of poison which actually can be discharged at a single filling. With certain types of feeding devices it has been found that there is so much back draft from the air duct when the hopper is only partially filled that, although the hopper may hold 4 or 5 pounds of material, only 1 or 2 pounds could be discharged before the back pressure interfered so seriously with the feeding that it was necessary to refill the machine. In such cases, of course, the poundage which must be carried but can not be discharged is simply a dead weight and so much loss in machine efficiency. In the selection of a hand duster, therefore, it should be determined how nearly empty the machine can be operated and a satisfactory discharge of poison still secured.

WEIGHT AND BALANCE OF GUN.

It is difficult to set a definite limit on the weight of the machine, as this depends largely upon its balance. A well balanced machine with the center of gravity very close to the operator naturally causes much less strain upon him than a poorly balanced machine of the same weight with the center of gravity farther forward. A maximum weight of from 18 to 20 pounds for a well balanced gun with full hopper probably is not too much, but to make a machine any heavier than this would be inadvisable unless the operation of the machine was much easier than is the case with any existing models. The strain of operating a hand gun lies not so much in the labor of turning the crank as in the task of combining the operations of walking, cranking, and directing the machine. One of the most important points is to have the dust chamber, which is naturally the heaviest part of the machine, as much to the rear as possible, thus reducing the leverage on the operator.

The machines now utilized may be divided into two classes, according to the manner in which they are carried, namely, those which rest against the side of the operator and those which are held against his abdomen. Each class appears to have its advantages and disadvantages but from observations of laborers while employed in this work it appears that a gun which rests against the abdomen seems preferable, especially if it is furnished with a broad contact surface.

ELEVATION OF DUST DELIVERY.

The height at which the dust cloud must be delivered must be taken into consideration in planning a machine. Of course, the plant height of cotton varies widely in different districts and during different seasons, but as a rule it is necessary to direct the dust cloud from a hand gun at a rather high elevation because most of the cotton is dusted comparatively late in the season when the plants usually have reached a height of from 3 to 4 feet or more. In most hand-gun work it is necessary to have the nozzle at least horizontal with the gun or in some cases even higher than the main body of the gun. Furthermore, it is necessary to send the dust rather directly into the plants, and this is only feasible with a fairly short pipe uniting the gun and the nozzle. Generally speaking, it has been found best to utilize a delivery pipe from 3 to 4 feet in length—certainly no longer than this. In addition, the take-off from the gun proper should be so arranged that when the gun is held in a normal position the delivery pipe will extend forward horizontally and not be directed downward, as is usually the case.

INEFFICIENCY OF TWO-ROW HAND GUNS.

In several instances the attempt has been made to use hand guns for two rows at a time instead of one. This has been accomplished by putting a Y branch on the outlet pipe and thus leading to two nozzles supposedly separated about the width of an average row.

This is not advisable, as thus far no hand gun has been developed which has more power than is necessary for dusting the single row efficiently.

NOZZLES.

As to the nozzles, there are a number of types of these and they usually consist merely of some form of spreader device which flattens the dust cloud as delivered from the outlet pipe, thus making it cover a greater area. Several forms of nozzles seem equally satisfactory, and in selecting the nozzle it is necessary only to note that it is arranged so that it spreads the dust cloud instead of breaking the force of it. In some devices the air current is directed against some form of deflector which tends to reduce the air current so that the efficiency of the dusting is reduced. The nozzle openings must have a fair width in their narrowest dimension, for they are frequently trailing in wet cotton plants and if too narrow and confined this moisture will soon cause them to clog. Furthermore, even the best of nozzles will clog occasionally and should be readily accessible for cleaning.

DUST-FEEDING DEVICES.

A number of feeding devices have been utilized and several have proved satisfactory. The primary requirement is a quick, simple, and positive adjustment which will give a delivery range of from practically nothing to a maximum of about 20 to 25 pounds to the acre. In other words, the maximum delivery of the feeder when wide open should be about four-tenths of a pound per minute. The feed should also be of such a type that no dust is delivered into the air duct when the fan stops. Special difficulty has been experienced with certain types of guns with open slits or holes for gravity feeding which allow the dust to fall through into the air duct when the fan is stopped; when guns of these types are started again the pipe clogs and either blows the powder out in lumps or actually stops up and makes it necessary to take the machine apart in order to clear it. While cotton plants are planted continuously in the row, there are always numerous skips in the stand where it is desirable to stop the machine for a few steps, and the same is true at row ends. Consequently, a machine can not be satisfactory for cotton dusting which has this tendency to clog.

GENERAL CONSTRUCTION.

In the machines utilized so far the general housing construction has been of two types. In one case the fan and hopper have been housed separately, while in the other the two are included in the same general housing. Apparently the latter form is preferable, as it adds greatly to the general rigidity of the machine and seems to be much less subject to breakage in handling, due to more compact construction. This also affords an opportunity for shortening the weighty portion of the machine and thus holding the center of gravity closer to the body of the operator.

All guns which have proved satisfactory so far have been of a rotary fan type, giving a continuous blast of air. A few models have been tested which were equipped with a bellows arrangement and leverage device giving an intermittent current of air, but these have proved totally undesirable for this work because a continuous flow of dust is absolutely essential. Furthermore, these machines have so far failed to give the volume of air current desired.

In future construction every feature of the hand gun must be considered from the standpoint of making it as strong as possible. It is needless to go over many points in detail, but it should be remembered that every joint in the machine should be made in the most rigid manner. Of course, most of this work is done by crimping and soldering, and experience has shown that much improvement can be made and increased service rendered by the guns if this work is done more carefully than is usually the case. For example, one trouble experienced with the machines as they were originally constructed was the longitudinal splitting of the delivery pipes at the joint. It was found, however, that with better workmanship this trouble could be practically eliminated. In the same way good workmanship and good material are essential throughout the guns. All of them depend upon some arrangement of gears for securing their fan speed, and much trouble has been experienced in the past owing to poor alignment of these gears. The question of bearings is quite an important one also. Many dust guns have been built with only the crudest form of bearings, such as holes drilled through the iron framework. This not only greatly increases the friction and therefore the difficulty of turning the machine, but also causes rapid wearing of the parts and quickly results in bearing or gear trouble. In reality, any piece of machinery operating at the speed at which these fans are supposed to turn should certainly be equipped with either ball or roller bearings. Owing to the continued presence of calcium dust in the air it is desirable to have these bearings as well protected as possible, as this dust has a tendency to mix with the oil and form a gummy substance which greatly retards their operation.

Whenever possible, it is desirable to arrange some sort of housing for the protection of the outside gearing on the machine. The gun is in contact with the cotton plant so much that the leaves are constantly working into the gears, if exposed, and filling up the teeth so that these are choked and thrown out of alignment and the difficulty of operation is greatly increased.

Another comparatively minor difficulty which has, however, caused much trouble in the past has been the method of fastening the straps utilized for supporting the guns. These are made of cloth webbing and as a matter of convenience in manufacturing, the different sections are usually riveted to the hooks fastening them to the machine. Many forms of rivets have been tested but thus far one has not been

found which will not pull out of the webbing after very little use. Consequently, it is desirable to have these sewed instead of riveted, and if any rivets are used they should be of rust-proof material. In this connection the ordinary type of eye soldered to the machine, to which these straps are fastened, has always proved too weak and has pulled off very quickly. It is advisable, therefore, to have these eyes riveted as well as soldered to the gun housing.

As a rule the opening for filling the hopper is so small that it is necessary to use some type of funnel and this is subject to considerable clogging. The opening for filling the hopper, therefore, should be made as large as possible.

Another point which must be determined entirely by the type of construction in each particular gun but one which it is well to bear in mind is the desirability of having as many parts as possible accessible for quick and convenient repair. Every additional part which can be reached conveniently for repair or replacement adds that much to the value of the machine.

The best machine is one which will give the maximum service with the minimum attention under very rough handling and which will cause the least possible strain on the operator. It seems so difficult, however, to attain this happy combination that from present prospects the future use of hand guns in cotton-dusting work seems comparatively limited, especially when other types of machines of larger capacity shall have been developed. In this connection, one of the most promising types now under consideration is what might be called a saddle model. Such a gun is now being evolved experimentally at the Delta Laboratory. The idea is to build a gun which will rest solidly on a saddle and so arranged that the rider can crank the machine while sitting in the saddle. Thus it will be possible to increase considerably the hopper capacity as well as the fan power, and it seems feasible to arrange some scheme by which the dust can be directed backward through two pipes leading out on each side of the mule to the nozzles, so that two rows can be covered at a trip. Furthermore, it should be possible to equip a machine of this type with some double-crank arrangement by which the operator could run the machine with either one or both hands and considerably reduce the labor of operation.

POWER MACHINES.

As has been mentioned, it was necessary to secure machines of a larger capacity for handling the work when the dusting was begun on an extensive scale. The only machines at that time which appeared to meet the needs were orchard dusters which for their original use could be mounted on almost any kind of wagon or truck. To adapt an orchard dusting machine to cotton dusting conditions it was necessary to mount it on a specially built truck and equip it with a

distributing system which would carry the dust to a number of rows at a time. Although these machines with everything working properly were capable of covering a large acreage in a day, many difficulties were experienced when they were placed in practical use. The trucks as built at first were too light and much breakage was the result. In one instance, in which seven machines were used on one plantation, it was a daily occurrence to carry one or more of the machines to the blacksmith shop to have the axles welded.

The distributing systems, which in most cases carried five nozzles, gave continuous trouble from the dust sticking and clogging the pipes, thus causing serious loss of time in clearing them. The nozzles of this system were spaced $4\frac{1}{2}$ feet apart. Thus in the five-row machines the distance from center to center of the outside nozzles was 18 feet, and considerable bracing was necessary on the back end of the machine to support the piping. In moving about from field to field it is usually necessary to remove the end sections of the pipe in order to get through gates, etc. The average width of a gate in the cotton belt is about 10 feet, so that even with the end sections of the pipe removed, very careful driving was required in passing through them and it was not an uncommon occurrence for the distributing system to be caught against trees or fence posts and for the machine to be damaged to a serious extent. Considerable time was required in taking down and reassembling these distributing systems for moving and often the reassembling was done rather loosely, resulting in either lost or broken parts. Figure 4 gives a good idea of the general appearance of one of these power dusters in operation.

FIG. 4.—Power machine in operation in a cotton field.

TRUCK.

The trucks of these machines had a wheel base of 72 inches and a tread of 52 inches; the wheel base being made as short as possible to accommodate the platform, and the tread such as would clear the cotton rows in the district where used. The tread on the machines used to date has been the same for all regions. As will be discussed later, however, it will be necessary to change this.

It was a frequent occurrence on the first machines for the wheels to become warped or bent out of shape and for the tire to be flattened where it would strike stumps, drop into ditches, etc., but this has been overcome by making the hub larger to accommodate more and heavier spokes and using thicker material in the tire. Also the center of the tire had a channel or groove pressed in it to make it rigid. The front wheels were made smaller in diameter than the rear in order to allow them to turn back under the platform and permit short turning of the machine. The axles were bent or arched to give a clearance of 42 inches from the ground and it was at the bends in these axles that the great amount of breakage occurred. In the beginning, these axles were made of $1\frac{1}{2}$ inches square material and the bends made with a sharp corner on the inside or almost at a right angle; also, the thickness had been materially reduced in the bending process. On the trucks built for the 1919 season's work, the size of the axles was increased to $1\frac{3}{4}$ inches square, and all bends curved gradually instead of turning with a sharp corner on the inside. This construction proved amply strong to meet the conditions and no further trouble from this source was experienced.

On the earlier machines, although constructed for the front wheels to cut under for short turning, the clearance was not sufficient and if the truck was not standing level the frame would be slightly twisted and the top of the wheel would catch. The fifth wheel construction, held together by a kingbolt, caused considerable trouble from the fact that the parts were not rigidly fastened together, and that the kingbolt was drawn up so tight that it would not give sufficient freedom to the front wheel, when running over obstructions, to prevent twisting the entire frame of the machine. It was not uncommon for the nut on the kingbolt to be lost and for the front wheels to be pulled from under the platform in crossing ditches. Some of the trucks recently constructed have a fifth wheel with a hinge arrangement which will permit one of the front wheels to be raised a distance of about 16 inches without throwing any strain on the framework. This is a decided advantage in crossing ditches or on rough land.

So far the system for hitching the horses to the machine has been unsatisfactory in that the only provision made for carrying the singletrees has been from rigid framing running direct from the axle of the machine. This sort of a hitch throws all the load on one horse if the other is inclined to loaf and has proved so objectionable that users have in many cases rigged the machine with a set of

doubletrees. This, however, has not been thoroughly satisfactory since, owing to the high arched construction and elevation of the tongue, it brings the line of draft entirely too high on the team, but even with this objection it is preferable to the rigid hitch.

The platforms of the machine are $8\frac{1}{2}$ feet long by $4\frac{1}{2}$ feet wide, built of 2-inch tongued-and-grooved material with the boards running the short way and the edges bound with angle irons extending the entire length of the platform to prevent excessive warping and in addition strengthening the whole construction. Experience has proved that it was necessary to make these platforms of this heavy material, since oftentimes several barrels of dust are hauled to the field on a machine, and wood of any less thickness is not satisfactory to stand the strains of the load and does not hold the bolts satisfactorily for fastening the machinery and running gear to the platform. The platforms are supported by two channel irons running their entire length and resting on the rear axle and fifth wheel. Some machines have a heavy channel iron securely riveted to the frame channels extending across the back end the full width of the platform and forming a rigid support for the distributing system, while in others the distributing system is bolted to the back of the platform itself. This latter type is found very unsatisfactory in that the bolts will pull out owing to the great vibration or, when obstructions are struck with the piping, the planks will split off. This trouble is eliminated when the distributing system is bolted to the cross-channel as mentioned above.

ENGINE.

It can not be said that the engines used were unsatisfactory from the standpoint of engine construction. When a size large enough to furnish the power required was selected, very little trouble was experienced if they were given intelligent attention, but operated as they were by a class of labor which knew nothing about them they did cause considerable delay in the work, not so much by breakage as by being out of adjustment or in many cases only out of fuel or oil.

The engines used for the various power dusters varied from 2 to $3\frac{1}{2}$ horsepower. A few machines were equipped with $1\frac{1}{2}$-horsepower engines, but these proved too small for the work. Water-cooled engines have generally been used; consequently, it has been found necessary to put a cover or baffle over the top of the water hopper to prevent excessive splashing which would waste the water and sometimes scald the operator. Since the engine was naturally subjected to a great deal of dust, trouble was experienced by parts becoming gummed with a mixture of oil and dust. While no serious difficulty was experienced from the dust being drawn into the cylinders, still a great deal was carried in with the air, making necessary more frequent removal of carbon. The vibration of the engine has been decidedly objectionable; in fact, it tends to loosen parts on the whole machine and cause excessive packing of the poison dust in the hopper and in some cases introduces difficulties in the lighting system.

Much difficulty has been experienced with the belting on the power dusters. During the dusting season the machines are out in the weather most of the time, where they are subjected to extremes of moisture and heat, which make it hard for any belting to stand up under the service. So far, rubber or gum filled fabric belts have proved the most satisfactory, but, owing to the short distance between the pulleys over which some of the belts run, considerable slipping has occurred, and to overcome this the use of various belt dressings has been resorted to—usually some sticky material which causes dirt to collect on both belting and pulleys and to pull the rubber from the inside of the belt. Another source of trouble has been the use of belt tighteners, which were often adjusted to make the belt excessively tight, thus causing unnecessary friction on the bearings and wearing them rapidly. It is a common occurrence for the operator in adjusting the belt tightener to pull it as tight as possible and then not touch it again until the belt has become so slack that it slips on the pulley.

DUSTER.

The duster machinery proper, consisting of a fan, a dust container, or hopper, and the feeding mechanism, has been the source of considerable trouble, and careful consideration should be given to its selection and design. The fans used on the machines have varied in diameter from 9 to 15 inches, running at speeds of from 2,000 to 4,000 revolutions per minute. None of these fans has been capable of delivering as high a pressure as is desired. On some types of machines the fan has not been properly attached to the shaft to prevent it from working loose, which would at least reduce the blast and sometimes stop it completely. When only loose and still delivering a light blast, the difficulty is hard for the average operator to discover. Then, too, these fans were not constructed to prevent end thrust of the shaft from causing wear on the inside ends of the bearings and ends of the fan hub, which eventually allow the blades to come into contact with the housing, thus wearing down the edges of the blades and in some cases catching and breaking them.

Various schemes for feeding devices have been used. Some have rotating brushes which force the dust through perforated plates, the quantity of dust going through being regulated by opening or closing the perforations. Others merely permit the dust to feed by gravity through comparatively large openings. The latter method was used on the first machines but was not entirely satisfactory in that it was not positive and thus did not give the desired even flow of dust. To overcome this difficulty, a feeding device was designed and was patented under Government Patent No. 1282697. This device is an auger which can be raised or lowered and permits positive regulation of the feed from complete cut-off to the maximum quantity needed. Owing to the tendency of the dust to pack it is advisable to use some system of agitators in the hopper which will keep the dust loose and free to flow to the feeder.

The dust container or hopper should have a capacity of at least 3,000 cubic inches, or enough to hold 30 or more pounds of dust. It should be so shaped that all of its contents can flow by gravity to the feeding mechanism. The opening for refilling should be as large as construction will permit, as it will allow the filling to be done with greater rapidity and less waste of material than where the opening is small. Also it makes the interior much more accessible for making repairs and removing any foreign material carried in with the dust. On some machines there is a tendency for air from the air duct to be blown back through the feeder into the hopper. In cases where this is true, the hopper should be made air-tight to prevent the dust from being blown out. Where gear or chain drive is necessary to operate the feeder, agitator, etc., it should be of the best quality of material and workmanship. A great deal of trouble has been experienced from this source owing to the presence of dust and dirt both in tooth and sprocket gear mechanisms. Ordinary rough-cast gears and detachable link chains absorb considerable power and wear easily. The chains, in particular, if slightly worn and of much length, invariably start riding the sprockets and running off. Also it is a common occurrence for the operator to remove too many links and run the chains too tight, which is not only apt to break the chain but will also cause excessive wear on the sprockets and bearings.

LIGHTING.

The question of an adequate and serviceable lighting system is one that is not settled at the present date. The lighting apparatus, like the rest of the machine, must be simple. The requirements are that the light be strong enough to enable objects to be clearly distinguished at a reasonable distance, say 50 feet, particularly in the front and rear, for it is necessary for the operators not only to be able to distinguish the rows clearly in front but to see the dust cloud in the rear and to have plenty of illumination on the machine parts. The height of the burner of any light should be at least 36 inches from the platform in order to reduce the shadow of the platform and thus enable the driver to drive around obstructions with greater safety. Where it is necessary to use reflectors, the widest angle possible should be used in order that the light may be distributed to all sides of the machine.

Various lighting systems have been tried, but all have met with serious objections. Several types of carbide generators, such as were formerly used on automobiles, were tried and gave good light when in working order, but too much trouble was experienced with the generating systems due mostly to the fact that the water feed was unreliable. This was largely due to clogging of the wicks and the difficulty of cleaning and replacing them. Variation in the size of the lumps of carbide also caused trouble by irregular feed through the screens which produced an objectionable variation in the gas supply.

Experiments have been conducted on a light using a compressed carbide cake. This light has been found to be very satisfactory, and

it is believed that it will meet requirements in the field. It furnishes plenty of illumination, is automatic in control, and comparatively simple. The light is so constructed that the carbide cake is held in a container which is open at the bottom end and is submerged in water. When water comes in contact with the cake, gas is generated inside the container, producing a pressure which forces the water down and away from the cake until enough of the generated gas is used to lower the pressure to a point where the water again rises to contact with the cake, and gas generation again takes place. The carbide cakes are specially treated to prevent deterioration when exposed to the atmosphere, and are convenient to handle when the light is being charged. This light uses a reflector especially designed to meet the requirements of this work.

Gasoline lanterns equipped with mantles and pressure systems were tried, but the mantles proved too fragile to withstand the constant vibration to which they were subjected. Various spring mountings for these lanterns were tried, but did not prove effective, the principal difficulty being that a light spring which would absorb the engine vibration was too light to resist the heavy shocks experienced on rough land. Even with the engine removed, however, it was not possible to arrange a combination of springs which would protect the mantles. It is especially unfortunate that these lights can not be used, as they furnish an abundance of illumination in all directions and thus eliminate the necessity of reflectors, which is a very desirable feature. They are also quite easily detached from the machine for refilling or for other uses.

Compressed acetylene gas systems have given the best satisfaction from the standpoint of reliability, but for this particular work have, in addition to a rather high first cost, another very objectionable drawback. It is absolutely necessary to have at least two tanks for each machine and preferably three, in order to have a supply of gas on hand at all times. The cost of these tanks at the present time is approximately $20 each, which, added to the cost of necessary reflectors, makes the total lighting cost close to $75 per machine, which is too high. The question of getting tanks refilled is a serious one and practically eliminates the adoption of this system of lighting for general use. Since automobiles have almost universally adopted electric lighting systems, filling stations are becoming very scarce. Considerable time is taken up when the tanks are in transit; also, as a rule the recharging stations do not send a full tank until an empty one has been placed in the hands of the express company and the express receipt received by them. If the plantation is remote from the express office, considerable inconvenience is caused by the necessity for making trips to the express office to get the filled tanks and return the empty ones. During the busy season when the dusting is being carried on planters are unable to stop work and make a trip merely to get a tank.

It seems reasonable that some form of electric lighting could be utilized but when all the conditions are considered many points come up which appear to make it impracticable, although a system may be devised which will work successfully. A small generator could be installed on the machine to give satisfactory illumination when the machinery is running, but lights are necessary when moving from field to field and when the machine is undergoing repairs at night. A solution of this difficulty of course would be to use a storage battery, but considering the class of labor which operates the machines, this is out of the question. It also looks feasible to use dry cells with an extra set of lights for furnishing illumination when the generator is not running, but this would complicate the lighting system by increasing the number of parts and there would be trouble as a result of failure to provide extra dry cells and care for them properly.

DISTRIBUTING SYSTEM.

Considerable trouble has been experienced in getting a satisfactory system of carriers for delivering the dust to the plant rows. At the start these systems were built of ordinary iron pipe and fittings which proved unsatisfactory in many ways. The pipe was heavy and the use of the fittings objectionable in that they introduced irregularities which caught dust and caused the formation of drifts which eventually clogged the pipes. All turns were made with right-angle fittings which gave a great deal of trouble, not only from the dust sticking in them and their resistance to the air blast but from the working loose of the screwed joints. These in many cases were drilled and riveted to prevent this tendency to work loose but this was not satisfactory, as the excessive vibration would either shear the rivets or enlarge the holes and cause trouble in that way. The main pipes led away at right angles from each side of the fan discharge pipe, and smaller lateral pipes led from these to the nozzles. This arrangement made it necessary on three of the nozzles to use two right-angle bends, one from the fan discharge pipe and one where the lateral or nozzle pipe joined. On the line to the outside nozzles only one right-angle bend was required, as these pipes were a part of the main line and were bent with a gradual curve which brought the nozzles into their proper position; thus the only short bend was at the fan discharge pipe.

Rather extensive experiments were conducted to find a system which would eliminate sharp bends and give an even distribution of the dust which was not possible with the straight pipe and right-angle bend construction, since the end and center nozzles discharged the greatest quantity of dust, while the two intermediates discharged the least quantity. To form the most satisfactory dust cloud it is desirable to have the two end nozzles give the heaviest discharge, with those inside decreasing their discharge to the center where it is lightest, the reason being that there is always a tendency for the dust cloud to drift more or less. Consequently, some of the cloud coming out of the end nozzles drifts toward the center, and in order

to get the density uniform the discharge of the center and intermediate nozzles should be less than that of those on the end. In order to accomplish this a distributing box or chamber was built and attached to the fan outlet. This box had outlets for the five discharge lines. Between the outlets were adjustable partitions which could be set to divert the desired proportion of dust to the different nozzles. Rubber tubing was used for the discharge lines. This tubing was carried to the nozzles by means of framework built up of angle irons in such a way that they would permit raising and lowering the nozzles, as well as allowing the end nozzles to be folded in against the side of the platform for moving.

Tests were made on the straight pipe system where all the laterals leading to the nozzles were the same size ($1\frac{1}{4}$ inches in diameter) and it was found that 26.64 per cent of the dust went through each end nozzle, 18.45 per cent through the center, and 13.13 per cent through each intermediate. It was found that by decreasing the size of the center pipe from $1\frac{1}{4}$ inches to 1 inch the distribution was more nearly what was desired. This changed the results so that the discharge from the different points was as follows: End nozzle, 28.45 per cent; center nozzle, 13.32 per cent, and intermediate, 14.84 per cent. Where the distributing box with the adjustable partitions was used it was possible to get any adjustment desired from complete cut-off of any pipe to its maximum carrying capacity.

Difficulty has been experienced in getting satisfactory construction of the framework for carrying the distributing systems. As before stated, they are subject to much vibration and shock and must have some sort of a hinge to permit the end sections to fold in, or a method of unjointing them so that they may be carried on the platform when necessary. If constructed to be unjointed, too much time is consumed in tearing down and reassembling. Where hinged joints have been provided they have in all cases been too weak, with the result that a great deal of breakage occurred.

The elevation of the nozzles was regulated by swinging them through an arc of 90°, or from a horizontal position for tall cotton to a vertically downward position for the small cotton. The nozzles were controlled and held at any desired height by means of levers. On some machines separate levers were provided for controlling the nozzles on each side of the fan discharge. This, however, is not as satisfactory as having a single lever which will control the entire system. A difficulty experienced has been a tendency toward too light construction of this controlling mechanism, as it must absorb a large part of the shock from the vibration and bouncing of the whole distributing system. The greatest trouble has been with the clamps which attach the pipe to the hand lever. These clamps, as sent out from the factory, have invariably broken or slipped on the pipe and the only satisfactory remedy has been to replace them with larger ones made at the local blacksmith shop, and even these have a tendency to slip on the pipe. This difficulty can be remedied

by some type of positive fastening of the clamp to the pipe. Owing to the frequency with which it is necessary to elevate the nozzles very quickly to prevent them from striking some obstruction, all machines must be provided with some positive and infallible lifting device.

The nozzles on the original machines were not constructed for night operation when dew was on the plants; and they did not distribute the dust to the best advantage, in that most of it was blown straight out from the center of the nozzle instead of being spread out fan shape to cover the largest area possible. To overcome these difficulties a nozzle was designed with a flaring lip or bell on the outer end to prevent the throat or slot, through which the dust emerges, from coming in contact with the wet plants. To get a better spread of the dust two deflecting partitions were put in the nozzle and so placed that they caught the correct proportion of the dust and spread it through the entire nozzle. The positions of these partitions were determined by experiment, and no changes in the adjustment were ever required. Some of these nozzles were made of cast iron and proved too heavy, owing to the additional strain placed on the piping and framework. They were also quite easily broken on striking any obstruction. In many cases they were broken by the operators during the process of thumping to jar loose any collection of dust which might have gathered in them. Nozzles made of pressed sheet metal have the advantage of being comparatively light and are able to stand much rougher usage than those of cast iron, and when damaged can often be bent back into serviceable shape. In making a nozzle all square corners should be avoided, as they catch dust and start drift formation.

EXHAUST.

The difficulty experienced with some machines in keeping the dust from lodging in the piping and feeder was relieved by connecting the engine exhaust to the fan discharge pipe immediately beyond the take-off from the fan, where the force of the exhaust would strike the feeding mechanism and keep it clear. The impulse also would keep drifts from forming at bends and irregularities in the piping. When inflammable compounds are being used as insecticides this scheme should be avoided, as it is possible for particles of hot carbon or flames from the exhaust to ignite the dust and cause an explosion. The adjustable distributing box, the improved nozzles, and the idea of connecting the exhaust to the fan discharge are all covered by Government patent No. 1282697 and are available for free use by all.

ADVANTAGES AND DISADVANTAGES OF THE POWER DUSTERS.

From the general ideas given of the conditions to be met, the advantages and disadvantages of the power machines may be summed up as follows: They are capable when working properly of covering a large acreage in a short time, for an acre can be treated in about 10 minutes; also, there is room on the platform for carrying

a good supply of dust, it being possible not only to keep a 200-pound barrel on the machine when operating but to tie on two or three additional barrels when going to the fields. On the other hand, they are heavy, weighing approximately a ton, and rather cumbersome to handle as field machines. The four wheels do more or less damage to plants in turning at row ends and in getting around obstructions in the field. The numerous parts of both the truck and dusting machinery require close attention and a fair knowledge of mechanics to keep them in working order. Experience of the past two years has proved that the average laborer available is not capable of caring for and operating the engine properly, and that he can not be depended upon to locate trouble or make adjustments and repairs. The distributing system when carrying five nozzles is awkward to handle around obstructions and in turning close to fences. Then, too, considerable time is consumed in getting the machine in shape for moving and in reassembling it for a new start.

WHEEL-TRACTION DUSTER.

The many difficulties experienced with the power duster emphasized the need of a more simple machine which would eliminate as many of the objectionable features as possible and still give the service. The idea in mind was to avoid the use of an engine, reduce the weight of the machine, and make it possible for the driver alone to operate the machine. Consequently, in 1919, an experimental machine was built and tested which incorporated these ideas. This machine, as can be seen in figure 5, is a two-wheel, arched-axle cart duster, with the power furnished by the traction wheels, which have sprocket chains running from them to drive a jack shaft on the cart platform. This jack shaft carries ratchets on the ends, and a friction clutch through which the power is transmitted to the mechanism for operating the fan and feeder. The ratchets on the ends of the shaft engage the small sprocket wheels and permit the traction wheels to run backward without turning the shaft, so that when turning at the row ends one wheel can drive the shaft and keep the machinery running, thus giving a continuous flow of dust. The friction clutch permits starting the machinery gradually, thus avoiding sudden strains and a heavy starting load on the team.

The fan and dust hopper are exactly the same as those used on some of the power machines, the only changes being the use of a V belt for the fan drive to secure good contact, and the positive auger feed previously mentioned which insures a steady flow of dust. An iron pipe distributing system carrying three nozzles, but otherwise similar to that on the power machines, was used. The end sections of this piping were made removable to allow the machine to go through any opening that the tread would permit.

This duster, although constructed merely to try certain principles, was put in the field and operated continuously throughout the dusting season with very satisfactory results. The load on the team was

not more than that of pulling the power machine. Comparatively little time was lost in making repairs or adjustments. One man drove and operated the machinery without difficulty. During the season's run this machine covered as large an acreage as the power machines, for since it carried only three nozzles it was much more easily moved from field to field and made closer and quicker turns at row ends and around obstructions, with less damage to the plants. No time is lost from engine trouble or in looking after numerous truck and distributing system parts. The distributing system with only three nozzles permits lighter construction and, being comparatively short (9 feet from center to center of outside nozzles), is subject to much less breakage than the distributors on the power machines where the distance is 18 feet between outside nozzles.

Another feature of this machine is that, since the feed auger is operated by the traction wheels, the rate of feed is always proportionate to the speed of the team, thus giving an even distribution of dust

FIG. 5.—Wheel-traction machine in operation in a cotton field.

at all times. Even when turning at the ends with one wheel doing most of the driving, a sufficient dust cloud is discharged to cover the plants effectively.

In designing a cart duster careful consideration should be given to every part. The traction wheels should be high enough to give easy traction with a tire width to allow plenty of ground contact. The hub should be equipped with roller bearings to prevent the excessive wear which would throw the sprocket drive wheel out of alignment and cause chain trouble. All chains preferably should be of the roller type, with the drive chains protected by guards or shields to prevent them from coming in contact with the plants, and to keep out as much dirt as possible.

The arrangement of the machinery on the platform should be such that it will use a minimum of space, for room is necessary for the driver's seat, the lighting system, and a 200-pound barrel of poison. The size and location of the platform with respect to the axle should be such that the load is balanced to prevent excessive weight coming on the horses' necks and yet not so far back that there will be ob-

jectionable tipping upward of the tongue when going down hill with the machine out of gear or when crossing ditches.

The neckyoke and doubletree should be of arched construction to give clearance over the plants. The doubletree, or whatever method of hitching is used, should be so constructed that the duty of pulling the whole load can not come on one horse without being detected by the driver.

With this machine the question of tread and axle clearance is probably even more important than with the power machine, since, having only two wheels, it would, with a high axle and too narrow a tread, have a tendency to be top-heavy and tip over easily. Generally speaking, however, in the districts where the cotton is planted in narrow rows the plants are comparatively small and the height of the cart can be reduced in proportion to the tread required. This will probably result in the production of several sizes of machines adapted to the different districts, but for the present the plans are for the production of a single size of machine having a 48-inch tread and a 42-inch axle clearance. This will undoubtedly serve in any cotton having a row width of more than 36 inches, and for the present it seems best to avoid the treatment of the cotton planted in narrower rows, as it is generally rather low in total production per acre and also subject to comparatively light weevil injury. Until poisoning has advanced further beyond the experimental stage better results can be secured by confining the work to the cotton where there is the greatest loss in production due to the weevil, and this is nearly always found in the districts where reasonably wide rows are used.

Attention has also been given to a machine which would straddle two rows and carry four nozzles, but this duster would require a very wide hitch and would be very difficult to handle in the field.

Consideration has been given the idea of building a machine with an adjustable axle which would allow variations in both height and width, but this is objectionable in that the many parts thus required would increase the weight and weaken the construction more or less. Furthermore, such an arrangement would undoubtedly be so complicated that the labor available for operation would have great difficulty in making adjustments.

SUMMARY AND CONCLUSIONS.

Experiments for the past few years in poisoning cotton for boll-weevil control have shown that profitable results can be secured on a practical basis if correct methods are followed. It has been found, however, that the poison must be applied in the form of a dry dust and that much of the success of the operation depends upon the dusting machinery available. Consequently, in either constructing or purchasing machinery for boll-weevil control it is necessary to consider carefully the many requirements of the work in order to make sure that the machinery will serve the desired purpose. The extent of weevil-infested territory is so enormous and the interest

shown by the planters so great that with the present facilities for the production of dusting machinery it is going to prove impossible to meet the demand. Consequently, every effort should be made toward making all machines which are put out for the market as satisfactory as possible and, furthermore, all farmers should inform themselves thoroughly on the requirements of a satisfactory dusting machine, so that in case an unsatisfactory machine is offered, they will be able to detect its faults in advance of purchase, and thus protect themselves from loss and possible failure of the poisoning operation. In case of further questions not covered by the present bulletin, all are invited to correspond with the Delta Laboratory at Tallulah, La., and the best advice available will be gladly furnished.

It has been found that cotton dusting differs radically from the operation of any other insecticide treatment now utilized, and that quite a number of special factors control the construction of the cotton-dusting machine. These are: (1) Type of labor; (2) areas to be treated, both in plantation and in field; (3) field conditions, such as row length, stumps, etc.; (4) necessity of night operation; (5) characteristics of poison utilized; and (6) type of dust cloud required. All of these factors affect so decidedly the operation of cotton dusting that unless the prospective manufacturer studies them carefully and thoroughly understands them, he can not expect to build a dusting machine which will prove satisfactory in field service.

The various types of machines, including hand guns, wheel-traction dusters, and power machines, have been tested extensively and the foregoing pages explain in detail the difficulties which have been experienced in the operation of each type of machine and the steps which have been taken to overcome these difficulties, as well as suggestions for additional measures which may be taken in the future. Experiments to date have indicated that the hand gun has a decidedly limited use. The treatment of considerable areas (that is, over 50 acres) with a number of hand guns has not proved practicable under most conditions. Consequently, once an adequate supply of dusting machines is available, it seems that the use of the hand gun will be limited to exceedingly small areas of cotton and as an adjunct to large machinery. The power machines have proved fairly satisfactory but the desirability of eliminating the engine has become so pronounced that the present tendency is to favor the wheel-traction machines which have been described in some detail.

It must be understood, of course, that the present bulletin is to be considered only as a progress report and is issued solely for the purpose of making available the information on the subject of dusting machinery which has been secured so far. The writers do not wish to be construed as intimating that the statements and conclusions given in this paper are in any way final. Dusting machinery for cotton poisoning is strictly in an experimental stage and it is to be expected that improvements will be developed from time to time for years to come.

O

FARMERS' BULLETIN 1098
UNITED STATES DEPARTMENT OF AGRICULTURE